(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平7－337046

(43)公開日　平成７年(1995)12月22日

(51)Int.Cl.[6]	識別記号	庁内整理番号	ＦＩ	技術表示箇所
Ｈ０２Ｎ　2/00	Ｃ			

審査請求　未請求　請求項の数３　ＦＤ　（全 ８ 頁）

(21)出願番号　特願平6－147117

(22)出願日　平成６年(1994)６月６日

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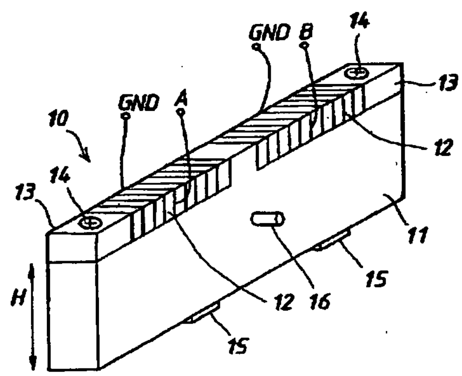
(54)【発明の名称】　超音波モータ駆動装置

(57)【要約】
【目的】　製品のばらつきや使用条件の変化に関わらず、常に安定して超音波モータを駆動することのできる超音波モータ駆動装置を提供することを目的とする。
【構成】　印加する交番電圧の周波数または位相を制御することによって、駆動子の超音波楕円振動が位相差π／４程度（または５π／４程度）の楕円となるように駆動する。



10　超音波振動子
11　弾性体
12　圧電素子
13　保持部材
14　ビス
15　摺動部材
16　保持ピン

【特許請求の範囲】

【請求項１】　弾性体と、この弾性体に固定された駆動子と、同弾性体に取付けられた複数の電気－機械エネルギー変換素子とから構成され、上記弾性体に縦振動と屈曲振動との合成振動を励起して、上記駆動子を超音波楕円振させる超音波振動子と、上記駆動子により駆動される被駆動体と、上記電気－機械エネルギー変換素子に交番電圧を印加する電源とを有する超音波モータ駆動装置において、

上記縦振動のみを検出する第１の振動検出手段と、

上記屈曲振動のみを検出する第２の振動検出手段と、

上記第１および第２の振動検出手段の情報に基づいて、上記駆動子に励起する超音波楕円振動の長軸方向のベクトルであって被駆動体に接近する方向のベクトルと、同超音波楕円振動の接線方向の速度ベクトルであって被駆動体が駆動される方向の速度ベクトルとによってなす角が鋭角となるように、上記複数の電気－機械エネルギー変換素子に印加する交番電圧の周波数と位相の少なくとも一方を制御する比較制御器と、

を具備することを特徴とする超音波モータ駆動装置。

【請求項２】　弾性体と、この弾性体に固定された駆動子と、同弾性体に取付けられた複数の電気－機械エネルギー変換素子とから構成され、上記弾性体に縦振動と屈曲振動との合成振動を励起して、上記駆動子を超音波楕円振動させる超音波振動子と、上記駆動子により駆動される被駆動体と、上記電気－機械エネルギー変換素子に交番電圧を印加する電源とを有する超音波モータ駆動装置において、

上記縦振動を上記被駆動体の移動方向を正の向きとして検出する第１の振動検出手段と、

上記屈曲振動を上記駆動子から被駆動体への方向を正の向きとして検出する第２の振動検出手段と、

上記第１および第２の振動検出手段の情報に基づいて、上記縦振動に対する屈曲振動の位相差θが、

$$0 < \theta < +\pi/2$$

または、

$$+\pi < \theta < +3\pi/2$$

となるように、上記縦振動の共振周波数以下で上記屈曲振動の共振周波数以上の周波数範囲で、前記複数の電気－機械エネルギー変換素子に印加する交番電圧の周波数と位相の少なくとも一方を制御する制御手段と、

を備えたことを特徴とする超音波モータ駆動装置。

【請求項３】　弾性体と、この弾性体に固定された駆動子と、同弾性体に取付けられた複数の電気－機械エネルギー変換素子とから構成され、上記弾性体に縦振動と屈曲振動との合成振動を励起して、上記駆動子を超音波楕円振動させる超音波振動子と、上記駆動子により駆動される被駆動体と、上記電気－機械エネルギー変換素子に交番電圧を印加する電源とを有する超音波モータ駆動装置において、

上記縦振動を被駆動体の移動方向を正の向きとして検出する第１の振動検出手段と、

上記屈曲振動を駆動子から被駆動体への方向を正の向きとして検出する第２の振動検出手段と、

上記縦振動の共振周波数が上記屈曲振動の共振周波数よりも高く設定され、該縦振動の共振周波数以下で該屈曲振動の共振周波数以上の周波数範囲において、該縦振動の交番電圧に対する振動の位相差δaと、該屈曲振動の交番電圧に対する振動の位相差δbが、

$$0 < (\delta a - \delta b) < +\pi/2$$

となる形状に形成された超音波振動子と、

上記第１および第２の振動検出手段の情報に基づいて、上記縦振動に対する上記屈曲振動の位相差θが、

$$\theta = \pi/4$$

または、

$$\theta = 5\pi/4$$

となるように、上記縦振動の共振周波数以下で上記屈曲振動の共振周波数以上の周波数範囲で、前記複数の電気－機械エネルギー変換素子に印加する交番電圧の周波数と位相の少なくとも一方を制御する制御手段と、

を具備しており、上記複数の電気－機械エネルギー変換素子に、位相が$\pm\pi/2$異なる交番電圧を印加することを特徴とする超音波モータ駆動装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は超音波モータ駆動装置に関する。

【０００２】

【従来の技術】一般に超音波モータにおいては、被駆動体に接触する駆動子を楕円振動させて駆動力を発生させている。このような楕円振動を発生させるには、原理的には互いに直交する方向の２つの振動を合成すればよく、より詳しくはＸ軸方向とＹ軸方向に同一周波数でかつ位相の異なる振動を加えればよい。したがって、この条件を満たす限り超音波モータ自体の構造としては様々な変形が可能であり、例えば積層型圧電素子を直交方向に２個組み合わせた構造や、上下振動用の直方体状の積層型圧電素子の側面に左右振動用の屈曲用の圧電素子を貼着した構造のものなどが知られている。

【０００３】そこで本出願人も特願平４－３２１０９６号において、直方体形状の弾性体の上面の３箇所に保持用弾性体を固定し、各保持用弾性体の間に２つの積層型圧電素子を挟持固定した構造の超音波振動子を提案している。この超音波振動子は、弾性体の縦振動と屈曲振動の共振周波数がほぼ一致する寸法に設計され、２つの積層型圧電素子に共振周波数でかつ位相の異なる交番電圧を印加する。すると、弾性体の底面に固定した駆動子に、縦振動による左右の振動と屈曲振動による上下の振動とが合成された楕円振動が発生する。この超音波振動子によれば圧電素子の圧電縦効果を利用するので、電気

ー機械変換効率が高く、低電圧で駆動できる効果が得られる。

【0004】

【発明が解決しようとする課題】ところが上述の先願の装置では、製品の個体差によるばらつきが大きく、必ずしも動作が安定しないという問題点があった。すなわち、詳しくは後述の実験結果に見られるように、縦振動の共振周波数と屈曲振動の共振周波数を厳密に一致させた場合でも動作が不安定であったり、縦振動の共振周波数と屈曲振動の共振周波数がほんの僅かずれている場合でも良好に動作するものや全く動作しないものがあり、その原因が不明であった。また、同一の製品についても温度変化により共振周波数が変化すると速度や推力が低下してしまうという問題点もあった。

【0005】本発明は上記問題点に鑑みてなされたもので、製品のばらつきや使用条件の変化に関わらず、常に安定して超音波モータを駆動することのできる超音波モータ駆動装置を提供することを目的とする。

【0006】

【課題を解決するための手段】発明者らは、駆動子の超音波楕円振動は位相差π／4程度（または５π／４程度）の楕円とするのが最適であって、大きな推力や速度が得られ、安定して動作することを見いだした。

【0007】そこで、上記目的を達成するために請求項１に係る本発明の超音波モータ駆動装置は、弾性体と、この弾性体に固定された駆動子と、同弾性体に取付けられた複数の電気－機械エネルギー変換素子とから構成され、上記弾性体に縦振動と屈曲振動との合成振動を励起して、上記駆動子を超音波楕円振動させる超音波振動子と、上記駆動子により駆動される被駆動体と、上記電気ー機械エネルギー変換素子に交番電圧を印加する電源とを有する超音波モータ駆動装置において、上記縦振動のみを検出する第１の振動検出手段と、上記屈曲振動のみを検出する第２の振動検出手段と、上記第１および第２の振動検出手段の情報に基づいて、上記駆動子に励起する超音波楕円振動の長軸方向のベクトルであって被駆動体に接近する方向のベクトルと、同超音波楕円振動の接線方向の速度ベクトルであって被駆動体が駆動される方向の速度ベクトルとによってなす角が鋭角となるように、上記複数の電気－機械エネルギー変換素子に印加する交番電圧の周波数と位相の少なくとも一方を制御する制御手段と、を備えたことを特徴としている。

【0008】また請求項２に係る本発明の超音波モータ駆動装置は、弾性体と、この弾性体に固定された駆動子と、同弾性体に取付けられた複数の電気－機械エネルギー変換素子とから構成され、上記弾性体に縦振動と屈曲振動との合成振動を励起される被駆動体と、上記電気－機械エネルギー変換素子に交番電圧を印加する電源とを有する超音波モータ駆動装置において、上記縦振動を上記被駆動体の移動方向を正の向きとして検出する第１の振動検出手段と、上記屈曲振動を上記駆動子から被駆動体への方向を正の向きとして検出する第２の振動検出手段と、上記第１および第２の振動検出手段の情報に基づいて、上記縦振動に対する屈曲振動の位相差θが、

$0 < \theta < +\pi/2$

または、

$+\pi < \theta < +3\pi/2$

となるように、上記縦振動の共振周波数以下で上記屈曲振動の共振周波数以上の周波数範囲で、前記複数の電気－機械エネルギー変換素子に印加する交番電圧の周波数と位相の少なくとも一方を制御する制御手段と、を備えたことを特徴としている。

【0009】また請求項３に係る本発明の超音波モータ駆動装置は、弾性体と、この弾性体に固定された駆動子と、同弾性体に取付けられた複数の電気－機械エネルギー変換素子とから構成され、上記弾性体に縦振動と屈曲振動との合成振動を励起して、上記駆動子を超音波楕円振動させる超音波振動子と、上記駆動子により駆動される被駆動体と、上記電気－機械エネルギー変換素子に交番電圧を印加する電源とを有する超音波モータ駆動装置において、上記縦振動を被駆動体の移動方向を正の向きとして検出する第１の振動検出手段と、上記屈曲振動を駆動子から被駆動体への方向を正の向きとして検出する第２の振動検出手段と、上記縦振動の共振周波数が上記屈曲振動の共振周波数よりも高く設定され、該縦振動の共振周波数以下で該屈曲振動の共振周波数以上の周波数範囲において、該縦振動の交番電圧に対する振動の位相差δa と、該屈曲振動の交番電圧に対する振動の位相差δb が、

$0 < (\delta a - \delta b) < +\pi/2$

となる形状に形成された超音波振動子と、上記第１および第２の振動検出手段の情報に基づいて、上記縦振動に対する上記屈曲振動の位相差θが、

$\theta = \pi/4$

または、

$\theta = 5\pi/4$

となるように、上記縦振動の共振周波数以下で上記屈曲振動の共振周波数以上の周波数範囲で、前記複数の電気－機械エネルギー変換素子に印加する交番電圧の周波数と位相の少なくとも一方を制御する制御手段と、を具備しており、上記複数の電気－機械エネルギー変換素子に、位相が±π／２異なる交番電圧を印加することを特徴としている。

【0010】

【作用】上記構成からなる本発明の超音波モータ駆動装置では、印加する交番電圧の周波数または位相を制御することによって、駆動子の超音波楕円振動が位相差π／４程度（または５π／４程度）の楕円となるように駆動する。このときの楕円振動は、図５（b）に示すように、位相差π／４では右上がりの楕円（駆動方向が右向

き：正のとき）を描き、位相差５π／４では左上がりの楕円（駆動方向が左向き：負のとき）を描く。いま、前者の場合について説明すると、駆動子は上昇しながら右方向に移動し、右最上点をすぎると、下降しながら左方向に復帰する軌跡をとっていることがわかる。つまり、駆動子が被駆動体を突き上げるように上昇するときには被駆動体に対する接触圧が高くなるが、この高い接触圧の状態で右方向に駆動するので、強力な駆動力が得られるのである。そして、駆動子が左方向に復帰するときには被駆動体から離脱するように下降するので力が及ばず、以上の繰り返しにより被駆動体は右方向に駆動されることになる。

【００１１】請求項１では、上記右上がりの楕円振動をより一般的に表現した。直交座標系においてＸＹ方向の振動の位相差がπ／４で右上がりの楕円となることはいわゆるリサージュ図形として知られているが、超音波振動子における振動成分は互いに直交するとは限らない。そこで、より一般的な表現としたのが請求項１である。

【００１２】請求項２では、直交座標系を想定し、位相差がπ／４の前後すなわち０～π／２の範囲にあることとした。

【００１３】請求項３では、より限定的に位相差をπ／４に特定し、必要な他の条件も付加した。

【００１４】以下、添付図面を参照して本発明に係る超音波モータ駆動装置の実施例を説明する。まず、本発明の実施例１を説明する。図１は超音波振動子を示す斜視図である。

【００１５】基本弾性体１１は、黄銅材を凸字型に形成したものであって、その寸法は幅３０㎜，奥行４㎜であって（凸部を除く）、高さHが６～９㎜の１０種類を試作した。凸部の寸法は幅４㎜，高さ２．５㎜，奥行４㎜である。基本弾性体１１の幅方向の中心部で底面から６㎜の位置にはφ２㎜のステンレスピン１６が圧入されている。

【００１６】積層型圧電素子１２は、電極処理された圧電素子を数十～数百枚積層したものであって、本実施例ではトーキン（株）のＮＬＡ－２×３×９型（寸法２㎜×３．１㎜×９㎜）を使用した。なお、積層型圧電素子１２の両端面以外の側面は厚さ０．５㎜のエポキシ系樹脂によって被覆されている。ここで図の左側の積層型圧電素子１２への電極をＡ，ＧＮＤとしＡ相と呼び、同様に右側の積層型圧電素子１２への電極をＢ，ＧＮＤとしＢ相と呼ぶことにする。

【００１７】２個の積層型圧電素子１２，１２は、基本弾性体１１の凸部を挟み込むように配置され、さらにその両側から基本弾性体１１にネジ１４止めされた保持用弾性部材１３，１３（幅４㎜，高さ２．５㎜，奥行４㎜）によって挟み込まれ、長手方向に圧縮力を受けた状態で固定されている。ここで積層型圧電素子１２の両端部と、基本弾性体１１の凸部および保持用弾性体１３とはエポキシ系の接着剤で固定される。積層型圧電素子１２と基本弾性体１１との接触面もエポキシ系接着剤で接着される。

【００１８】駆動子１５は、樹脂にアルミナセラミックスの砥粒を分散させた砥石材からなる幅３㎜，厚み１㎜，奥行４㎜の矩形状のものであって、基本弾性体１１の底面の両端から９㎜の位置に接着されている。この位置は、屈曲振動の腹に相当し、共振屈曲振動の振幅が極大値を示す位置である。

【００１９】次に、超音波振動子の動作について説明する。上記寸法の超音波振動子は、有限要素法によるコンピュータ解析によれば、図２（ａ）に示すような１次の共振縦振動、及び同図（ｂ）に示すような２次の共振屈曲振動がほぼ同一周波数で励起できる。その周波数は５３～５６ｋＨｚである。そこで、この共振周波数で振幅１０Vp-p の交番電圧をＡ相及びＢ相に印加した。まずＡ相とＢ相の位相を同位相にすると、図２（ａ）に示すような１次の共振縦振動が励起された。つぎに、Ａ相とＢ相の位相を逆位相にすると、図２（ｂ）に示すような２次の共振屈曲振動が励起された。さらに、Ａ相とＢ相の位相を９０度ずらすと、駆動子１５付近に超音波楕円振動を励起された。

【００２０】つぎに、上述の超音波振動子を使用した超音波リニアモータについて説明する。図３は超音波リニアモータの正面図である。図示の通り、この超音波リニアモータでは、超音波振動子１０によって、被駆動体たる移動部３２，摺動部材保持部３３，および摺動部材３４が、クロスローラガイドの固定部３０上を左右に駆動される。

【００２１】超音波振動子１０は、ピン１６によって２枚の保持板２１の間に枢着されており、保持板２１は取付部材２２にネジ２３止めされ、取付部材２２はリニアブッシュ２４により軸２５に沿って摺動自在に案内されている。また軸２５は基台２７に固定部材２６を介して固定されている。したがって、超音波振動子１０はピン１６まわりの回転の自由度と、ピン１６の上下移動による自由度とを有している。そして、前記固定部材２６と取付部材２２との間には調整ネジ２８により押圧力が可変できるバネ２９が介装されている。

【００２２】クロスローラガイドの固定部３０は基台２７にネジ３１止めされており、一方、クロスローラガイドの移動部３２には摺動部材保持部３３を介してジルコニアセラミックスからなる摺動部材３４が接着されており、超音波振動子１０の駆動子１５，１５と接触している。

【００２３】つぎに、この超音波リニアモータの動作を説明する。前述のように超音波振動子１０のＡ相とＢ相に５３～５６ｋＨｚの交番電圧を印加し、位相差を９０度（または－９０度）とする。すると超音波振動子１０の駆動子１５に超音波楕円振動が励起されて、移動部３

2が左右に移動する。そこで、前述のように高さHの異なる１０種類の超音波振動子を試作してモータ特性を評価した。その結果を次に示す。

【００２４】

【表１】

試作番号	縦共振周波数	屈曲共振周波数	モータ動作
0	５４．５０	５１．５０	×
1	５４．４０	５２．９０	○
2	５４．９０	５３．９０	○
3	５４．００	５３．６０	○
4	５４．４０	５４．０５	○
5	５４．７０	５４．６０	○
6	５４．５０	５４．５０	△
7	５４．９０	５５．３０	×
8	５４．７５	５５．６５	×
9	５４．４５	５５．８５	×

【００２５】表１において、モータ動作○印は良好に動作したことを示し、△印は動作するものの非常に不安定なもの、×印は全く動作しないか動作しても殆ど推力と速度の得られなかったことを示している。また、駆動周波数は表中の屈曲振動共振周波数以上で、縦振動共振周波数以下であった（表の単位はｋＨｚ）。この結果より、屈曲振動共振周波数が縦振動共振周波数以下でないと安定に動作しないことが明らかになった。

【００２６】以上の実験結果に対して、その原因を探るため次のような実験を行った。図４に示すように、超音波振動子１００の側面に振動検出素子として厚み方向に分極された圧電素子１１０を接着した。この圧電素子は幅１０mm，高さ３mm，厚み０．３mmである。接着位置は駆動子の直上である。振動子の表側の面には分極の向きが同一を向くように接着して直列に結線し、Ｆ１端子とした。振動子の裏面には分極向きを相互に逆にして、Ｆ２端子とした。図２の振動モードからわかるように、Ｆ１端子は弾性体の縦振動のみを検出し、Ｆ２端子は屈曲振動のみを検出する。

【００２７】さて、試作番号０～９までの超音波振動子について、Ｆ１，Ｆ２端子により電圧印加時の縦振動，屈曲振動を同時に検出した。その結果を図５に示す。同図において、上方に位置する被駆動体が左右方向に駆動される。また、正負とあるのは、正方向駆動時と負方向駆動時を表している。

【００２８】図５（ａ）は、試作番号０の振動子の振動形状である。ほとんど直線往復振動であるのがわかる。この場合には動作しないか、もしくは動作するものの殆ど速度，推力がでない。

【００２９】図５（ｂ）は、試作番号１～５の振動子の振動形状である。右上がりの楕円になっている。この場合には良好に安定して動作する。特に縦振動に対して屈曲振動の位相差が＋π／４（正方向駆動のとき）、または５π／４（負方向駆動のとき）となったときに最大の推力，速度が得られた。

【００３０】図５（ｃ）は、試作番号６の振動子の振動形状である。図には真円が示されているが、実際には縦振動と屈曲振動の振幅差によって縦長または横長の楕円になる。このときは動作が不安定であった。これから楕円の主軸が被駆動体の駆動方向と平行な場合には動作が不安定になることがわかった。

【００３１】図５（ｄ）は、試作番号７～９の振動子の振動形状である。この場合も動作しないか、もしくは動作するものの殆ど速度，推力がでない。

【００３２】以上の実験結果から、図５（ｂ）に示すような右上がりの楕円振動でないとモータが安定して動作しないことがわかった。

【００３３】このことは、ＸＹ直交座標系のリサージュ図形で考えれば、位相差がπ／４をはさんだ前後、すなわち０～π／２の範囲にあることを意味する。さらに、直交座標系以外においては、請求項１に記載したように、楕円振動の長軸方向のベクトルであって被駆動体に接近する方向のベクトルと、同超音波楕円振動の接線方向の速度ベクトルであって被駆動体が駆動される方向の速度ベクトルとのなす角が鋭角となることを意味する。

【００３４】次に、試作番号０～９の振動子に対して、印加電圧に対する各振動モードの振幅と位相の関係を周波数をスイープして調べたところ、図６のようになった。図において、ｆｌは縦振動の共振周波数であり、ｆｂは屈曲振動の共振周波数である。

【００３５】試作番号０の振動子の場合は、振動モード１に対応するのは縦振動モードであり、振動モード２に対応するのは屈曲振動であって、ｆｌとｆｂの間の位相差はπ／２であった。

【００３６】試作番号１～５の振動子の場合は、振動モード１に対応するのは縦振動モードであり、振動モード２に対応するのは屈曲振動であって、ｆｌとｆｂの間の位相差は０を越えπ／２未満であった。

【００３７】試作番号６の振動子の場合は、振動モード１に対応するのは縦振動モードであり、振動モード２に対応するのは屈曲振動であったが、両曲線はほとんど一致していた。このためｆｌとｆｂは一致しており、位相差は０であった。

【００３８】試作番号７～９の振動子の場合は、振動モード１に対応するのが屈曲振動モードであり、振動モード２に対応するのが縦振動であって、ｆｌとｆｂの間の位相差は０以上であった。

【００３９】以上の実験結果から超音波振動子としては、請求項３に記載したように、縦振動の共振周波数を屈曲振動の共振周波数よりも高く設定し、縦振動の共振周波数以下で屈曲振動の共振周波数以上の周波数範囲において、縦振動の交番電圧に対する振動の位相差δａと、屈曲振動の交番電圧に対する振動の位相差δｂが、０＜（δａ－δｂ）＜＋π／２となる形状に形成するのが

好ましいことがわかった。そしてこのとき積層型圧電素子には、縦振動の共振周波数以下で屈曲振動の共振周波数以上の周波数範囲で、位相が±π／２異なる交番電圧を印加すると安定した動作が得られる。

【００４０】しかしながら以上のことは、超音波振動子の共振周波数が一定の場合に成り立つのであって、実際の超音波振動子では使用中に３０℃程度の温度上昇が生じ、縦振動，屈曲振動ともに共振周波数が低下する。

【００４１】そこで、図７に示すような駆動回路とし、Ｆ１，Ｆ２端子からの検出信号を比較制御器に入力し、これらの振動検出手段の情報に基づいて、縦振動に対する屈曲振動の位相差θが、０＜θ＜＋π／２、または、＋π＜θ＜＋３π／２となるように、縦振動の共振周波数以下で屈曲振動の共振周波数以上の周波数範囲で、２つの積層型圧電素子に印加する交番電圧の周波数及び位相を制御した。すなわち、比較制御器は発振器の発振周波数を制御し、さらに移相器により位相差を制御する。これを増幅してＡ相，Ｂ相に交番電圧を印加する。

【００４２】本実施例では、以上の制御により超音波振動子の温度が変化して共振周波数がずれた場合であっても安定した推力と速度が得られた。なお、本実施例では積層型圧電素子を２個用いたが、３個以上の電気機械変換素子を用いた場合にも応用できる。

【００４３】

【実施例２】次に、本発明の実施例２を説明する。図８は本実施例の駆動回路を示すブロック図である。超音波振動子と、リニアモータの構成，作用は実施例１と同様である。本実施例では、超音波振動子のＡ相，Ｂ相に印加する交番電圧の位相差を±π／２に固定した。そして、比較制御器では周波数のみを制御した。すなわち、図８の比較制御器は、Ｆ１およびＦ２の情報に基づいて、縦振動に対する屈曲振動の位相差θが、θ＝π／４、または、θ＝５π／４となるように、縦振動の共振周波数以下で屈曲振動の共振周波数以上の周波数範囲で、２つの積層型圧電素子に印加する交番電圧の周波数を制御する信号を発振器に出力する。

【００４４】本実施例では、以上の制御により超音波振動子の温度が変化して共振周波数がずれた場合であっても安定した推力と速度が得られた。なお、本実施例は実施例１よりも回路構成が簡単になる利点がある。

【００４５】なお、本発明は上記実施例に限定されるものではなく、上記実施例では縦振動と屈曲振動を合成して超音波楕円振動を得たが、例えば、ねじり振動，すべり振動，呼吸振動，ひろがり振動などを組み合わせても同様に実現できる。また、上記実施例ではリニア型の超音波モータについて応用したが、移動体を回転体とすれば回転型の超音波モータへの応用も可能である。

【００４６】

【発明の効果】以上説明したように本発明の超音波モータ駆動装置によれば、超音波振動子の温度が変化して共振周波数がずれた場合であっても安定した推力と速度が得られる。

【図面の簡単な説明】

【図１】本発明による超音波振動子を示す斜視図である。

【図２】図１の超音波振動子の振動モードを説明する図である。

【図３】本発明による超音波リニアモータを示す正面図である。

【図４】本発明による超音波振動子を示す正面図および背面図である。

【図５】本発明の作用を説明する図である。

【図６】本発明の作用を説明する図である。

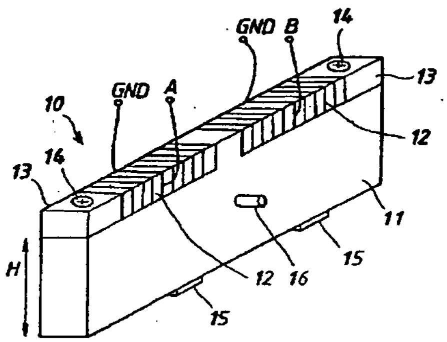
【図７】本発明の実施例１による超音波モータ駆動装置の駆動回路を示すブロック図である。

【図８】本発明の実施例２による超音波モータ駆動装置の駆動回路を示すブロック図である。

【符号の説明】

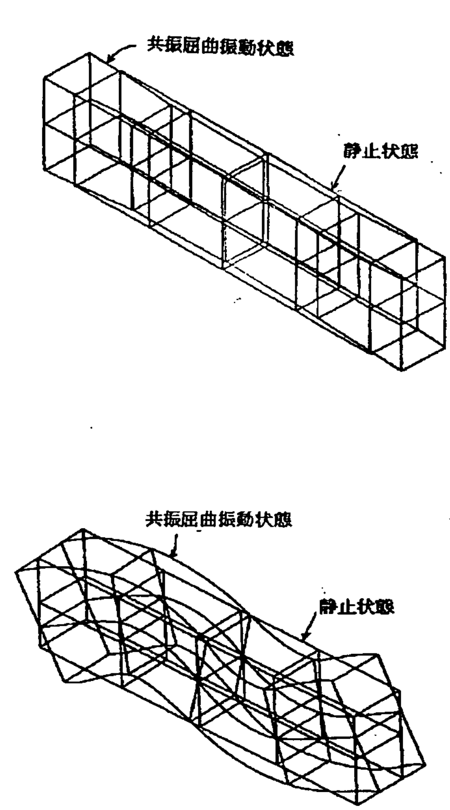
１０　超音波振動子
１１　基本弾性体
１２　積層型圧電素子
１３　保持用弾性部材
１５　駆動子
１６　ピン
２１　保持板
２４　リニアブッシュ
２５　軸
２７　基台
２８　調整ネジ
２９　バネ
３０　クロスローラガイド固定部
３２　クロスローラガイド移動部
３４　摺動部材

【図1】

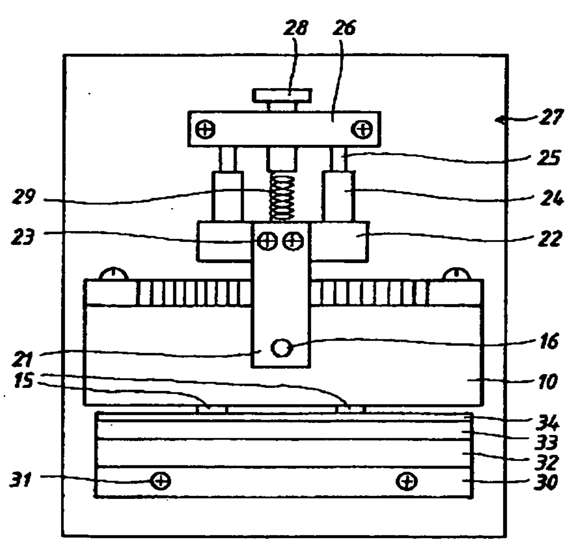


10　超音波振動子
11　弾性体
12　圧電素子
13　保持部材
14　ビス
15　摺動部材
16　保持ピン

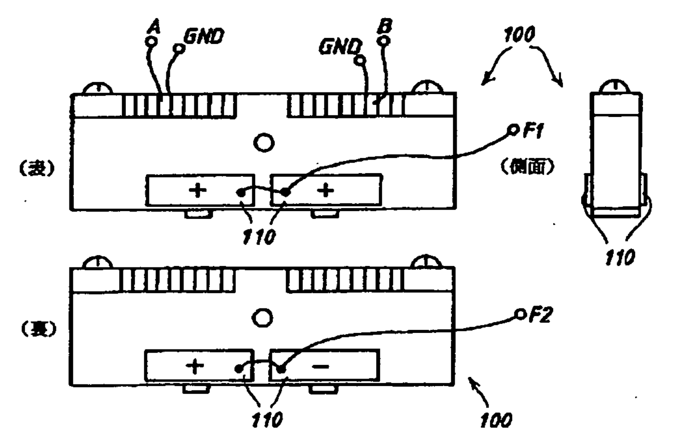
【図2】



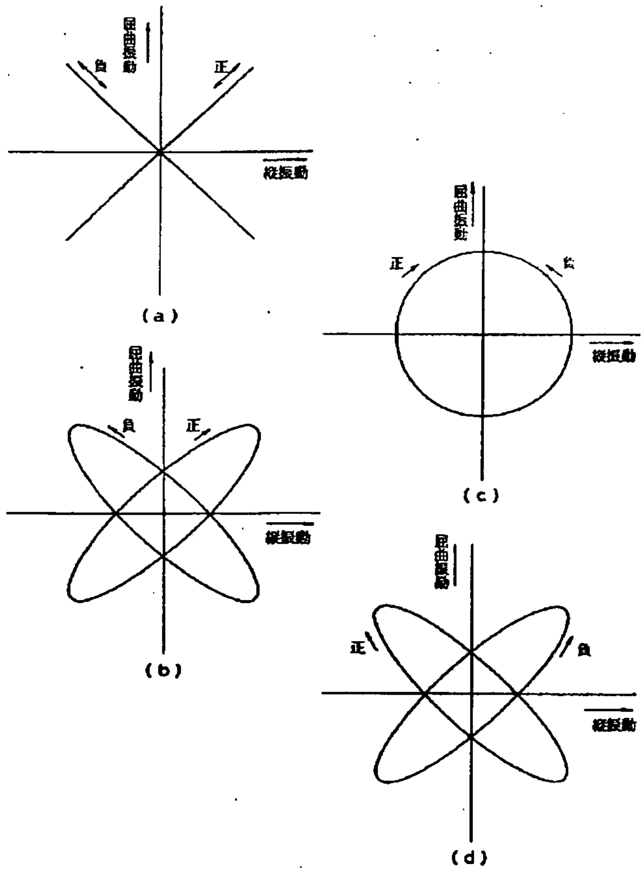
【図3】



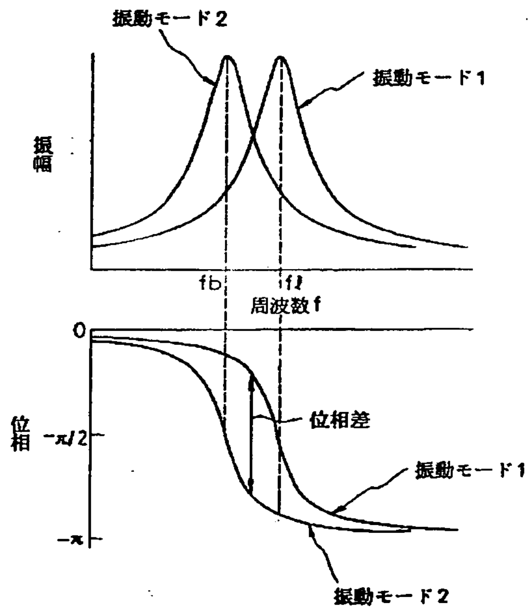
【図4】



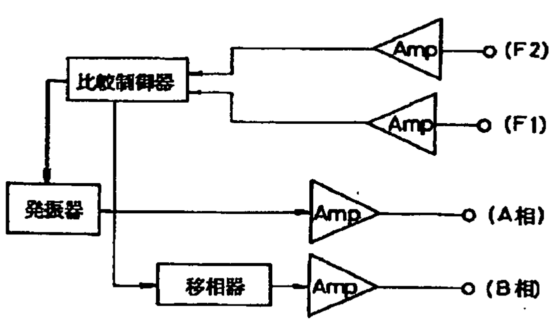
【図5】


屈曲振動
負
正
縦振動
(a)
(b)
(c)
(d)

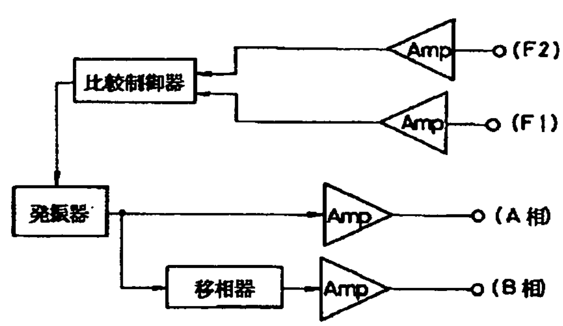
【図6】


振動モード2
振動モード1
振幅
fb
fl
周波数f
0
位相
-π/2
-π
位相差
振動モード1
振動モード2

【図7】


比較制御器
Amp
(F2)
(F1)
発振器
(A相)
移相器
(B相)

【図8】


比較制御器
Amp
(F2)
(F1)
発振器
(A相)
移相器
(B相)

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 07-337046
(43)Date of publication of application : 22.12.1995

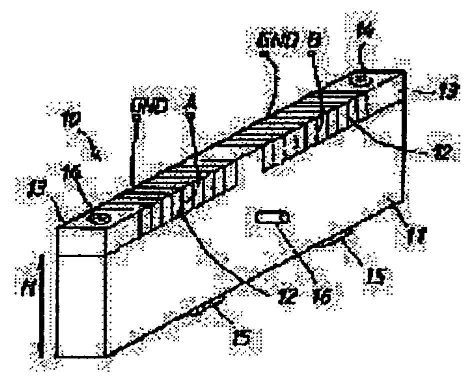
(51)Int.CI. H02N 2/00

(21)Application number : 06-147117
(22)Date of filing : 06.06.1994

(71)Applicant : OLYMPUS OPTICAL CO LTD
(72)Inventor : FUNAKUBO TOMOKI

(54) ULTRASONIC MOTOR DRIVE

(57)Abstract:
PURPOSE: To realize a stabilized operation while increasing the thrust and speed by controlling one of the frequency of phase of an AC voltage being applied to a plurality of electromagnetic energy conversion elements so that a vector in the direction approaching a driven body makes an acute angle with a speed vector in the drive direction of the driven body.
CONSTITUTION: Longitudinal and bending oscillations of a resilient body 11 are detected independently. Based on he detected information, one of the frequency or phase of an AC voltage being applied to a plurality of electromechanical energy conversion elements 12 is controlled so that the a vector in the longitudinal direction of an ultrasonic elliptical oscillation excited in a driver 15 and directed in the direction approaching a driven body makes an acute angle with a speed vector in the tangential direction of the ultrasonic elliptical oscillation and directed in the drive direction of the driven body. This structure stabilizes the operation while increasing the thrust and speed.



LEGAL STATUS

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CLAIMS

[Claim(s)]
[Claim 1] Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. In the ultrasonic motorised equipment which has the ultrasonic vibrator which carries out ultrasonic ****** of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects only the above-mentioned longitudinal oscillation, and the 2nd oscillating detection means which detects only the above-mentioned crookedness vibration, The vector of the direction which is the vector of the direction of a major axis of ultrasonic ellipse vibration excited to the above-mentioned drive child, and approaches a driven object based on the information on the above 1st and the 2nd oscillating detection means, So that the angle made by the velocity vector of the direction which is the velocity vector of the tangential direction of this ultrasonic ellipse vibration, and a driven object drives may turn into an acute angle Ultrasonic motorised equipment characterized by providing the comparison controller which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to two or more above-mentioned electric-mechanical energy sensing elements.
[Claim 2] Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. In the ultrasonic motorised equipment which has the ultrasonic vibrator which carries out ultrasonic ellipse vibration of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects the migration direction of the above-mentioned driven object for the above-mentioned longitudinal oscillation as a positive sense, The 2nd oscillating detection means which detects the direction of [from the above-mentioned drive child] a driven object for the above-mentioned crookedness vibration as a positive sense, the phase contrast theta of crookedness vibration of as opposed to the above-mentioned longitudinal oscillation based on the information on the above 1st and the 2nd oscillating detection means -- 0 < -- theta < -- +pi/2 or +pi < -- theta -- < -- Below with the resonance frequency of the above-mentioned longitudinal oscillation in the frequency range more than the resonance frequency of the above-mentioned crookedness vibration so that it may be set to +3pi/2 Ultrasonic motorised equipment characterized by having the control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to said two or more electric-mechanical energy sensing elements.
[Claim 3] Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. In the ultrasonic motorised equipment which has the ultrasonic

vibrator which carries out ultrasonic ellipse vibration of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects the migration direction of a driven object for the above-mentioned longitudinal oscillation as a positive sense, The 2nd oscillating detection means which detects the direction of [from a drive child] a driven object for the above-mentioned crookedness vibration as a positive sense, The resonance frequency of the above-mentioned longitudinal oscillation is set up more highly than the resonance frequency of the above-mentioned crookedness vibration, and it sets to the frequency range more than the resonance frequency of this crookedness vibration below with the resonance frequency of this longitudinal oscillation. phase contrast deltaa of vibration to the alternation electrical potential difference of this longitudinal oscillation Phase contrast deltab of vibration to the alternation electrical potential difference of this crookedness vibration 0 < -- (deltaa-deltab) < -- With the ultrasonic vibrator formed in the configuration used as +pi/2 Based on the information on the above 1st and the 2nd oscillating detection means, the phase contrast theta of the above-mentioned crookedness vibration to the above-mentioned longitudinal oscillation is theta. = pi/4 Or theta = Below with the resonance frequency of the above-mentioned longitudinal oscillation so that it may be set to 5pi/4 in the frequency range more than the resonance frequency of the above-mentioned crookedness vibration The control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to said two or more electric-mechanical energy sensing elements, Ultrasonic motorised equipment characterized by impressing the alternation electrical potential difference from which it provides and a phase differs ** pi/2 in two or more above-mentioned electric-mechanical energy sensing elements.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to ultrasonic motorised equipment.
[0002]
[Description of the Prior Art] Generally in an ultrasonic motor, ellipse vibration of the drive child in contact with a driven object is carried out, and driving force is generated. What is necessary is just to add in more detail vibration from which it is the same frequency and a phase differs to X shaft orientations and Y shaft orientations that what is necessary is just to compound two vibration of the direction which intersects perpendicularly mutually theoretically, in order to generate such ellipse vibration. Therefore, as long as this condition is fulfilled, various deformation as structure of the ultrasonic motor itself is possible, for example, the thing of the structure which stuck the piezoelectric device for the crookedness for right-and-left vibration on the side face of the laminating mold piezoelectric device of the shape of the structure which combined the laminating mold piezoelectric device in the two rectangular directions, and a rectangular parallelepiped for vertical vibration etc. is known.
[0003] Then, in Japanese Patent Application No. No. 321096 [four to], these people also fixed the elastic body for maintenance to three places of the top face of the elastic body of a rectangular parallelepiped configuration, and have proposed the ultrasonic vibrator of the structure which carried out pinching immobilization of the two laminating mold piezoelectric devices between each elastic body for maintenance. The resonance frequency of the longitudinal oscillation of an elastic body and crookedness vibration is designed by the dimension mostly in agreement, and this ultrasonic vibrator impresses the alternation electrical potential difference from which it is resonance frequency and a phase differs in two laminating mold piezoelectric devices. Then, ellipse vibration by which vibration of right and left by longitudinal oscillation and vibration of the upper and lower sides by crookedness vibration were compounded by the drive child who fixed to the base of an elastic body occurs. Since the piezo-electric longitudinal effect of a piezoelectric device is used according to this ultrasonic vibrator, electric-machine conversion efficiency is high and the effectiveness which can be driven by the low battery is acquired.
[0004]

[Problem(s) to be Solved by the Invention] However, with the equipment of above-mentioned point **, there was a trouble that dispersion by the individual difference of a product was large, and actuation was not necessarily stabilized. That is, when the resonance frequency of longitudinal oscillation and the resonance frequency of crookedness vibration were made strictly in agreement so that the detailed below-mentioned experimental result may see, or when actuation was unstable or it had shifted [whether the resonance frequency of longitudinal oscillation and the resonance frequency of crookedness vibration are merely slight, and], there were what operates good, and a thing which does not operate at all, and the cause was unknown. Moreover, when resonance frequency changed with temperature changes also about the same product, there was also a trouble that a rate and a thrust will decline.
[0005] It aims at offering the ultrasonic motorised equipment which this invention was not made in view of the above-mentioned trouble, and cannot be concerned with dispersion in a product, or change of a service condition, but can always be stabilized, and can drive an ultrasonic motor.
[0006]
[Means for Solving the Problem] It found out that a thrust and a rate optimal [a drive child's ultrasonic ellipse vibration] considering as an about (about [or] 5pi/4) pi/4 phase contrast ellipse and big were obtained, and artificers were stabilized, and operated.
[0007] Then, the ultrasonic motorised equipment of this invention which relates to claim 1 in order to attain the above-mentioned purpose Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. In the ultrasonic motorised equipment which has the ultrasonic vibrator which carries out ultrasonic ellipse vibration of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects only the above-mentioned longitudinal oscillation, and the 2nd oscillating detection means which detects only the above-mentioned crookedness vibration, The vector of the direction which is the vector of the direction of a major axis of ultrasonic ellipse vibration excited to the above-mentioned drive child, and approaches a driven object based on the information on the above 1st and the 2nd oscillating detection means, So that the angle made by the velocity vector of the direction which is the velocity vector of the tangential direction of this ultrasonic ellipse vibration, and a driven object drives may turn into an acute angle It is characterized by having the control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to two or more above-mentioned electric-mechanical energy sensing elements.
[0008] Moreover, the ultrasonic motorised equipment of this invention concerning claim 2 The driven object which it consists of [object] an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and has a synthetic vibration with longitudinal oscillation and crookedness vibration excited by the above-mentioned elastic body, In the ultrasonic motorised equipment which has the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects the migration direction of the above-mentioned driven object for the above-mentioned longitudinal oscillation as a positive sense, The 2nd oscillating detection means which detects the direction of [from the above-mentioned drive child] a driven object for the above-mentioned crookedness vibration as a positive sense, the phase contrast theta of crookedness vibration of as opposed to the above-mentioned longitudinal oscillation based on the information on the above 1st and the 2nd oscillating detection means -- 0 < -- theta < -- +pi/2 or +pi < -- theta < -- Below with the resonance frequency of the above-mentioned longitudinal oscillation in the frequency range more than the resonance frequency of the above-mentioned crookedness vibration so that it may be set to +3pi/2 It is characterized by having the control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to said two or more electric-mechanical energy sensing elements.
[0009] Moreover, the ultrasonic motorised equipment of this invention concerning claim 3 Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with

longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. In the ultrasonic motorised equipment which has the ultrasonic vibrator which carries out ultrasonic ellipse vibration of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects the migration direction of a driven object for the above-mentioned longitudinal oscillation as a positive sense, The 2nd oscillating detection means which detects the direction of [from a drive child] a driven object for the above-mentioned crookedness vibration as a positive sense, The resonance frequency of the above-mentioned longitudinal oscillation is set up more highly than the resonance frequency of the above-mentioned crookedness vibration, and it sets to the frequency range more than the resonance frequency of this crookedness vibration below with the resonance frequency of this longitudinal oscillation. phase contrast deltaa of vibration to the alternation electrical potential difference of this longitudinal oscillation Phase contrast deltab of vibration to the alternation electrical potential difference of this crookedness vibration 0 < -- (deltaa-deltab) < -- With the ultrasonic vibrator formed in the configuration used as +pi/2 Based on the information on the above 1st and the 2nd oscillating detection means, the phase contrast theta of the above-mentioned crookedness vibration to the above-mentioned longitudinal oscillation is theta. = pi/4 Or theta = Below with the resonance frequency of the above-mentioned longitudinal oscillation so that it may be set to 5pi/4 in the frequency range more than the resonance frequency of the above-mentioned crookedness vibration The control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to said two or more electric-mechanical energy sensing elements is provided, and it is characterized by impressing the alternation electrical potential difference from which a phase differs ** pi/2 in two or more above-mentioned electric-mechanical energy sensing elements.

[0010]

[Function] By controlling the frequency or phase of an alternation electrical potential difference to impress by the ultrasonic motorised equipment of this invention which consists of the above-mentioned configuration, it drives so that a drive child's ultrasonic ellipse vibration may serve as an about (about [or] 5pi/4) pi/4 phase contrast ellipse. as shown in <u>drawing 5</u> (b), in phase contrast pi / 4, the ellipse vibration at this time draws an ellipse upward slanting to the right, when it is forward a driving direction -- rightward :, and when it is negative a driving direction -- leftward :, it draws the ellipse of a left riser in phase contrast 5pi/4. When a drive child will move rightward, going up if the case of the former is explained now, and it passes over the right best point, it turns out that the locus which returns leftward is taken, descending. That is, when going up so that a drive child may thrust up a driven object, the contact pressure to a driven object becomes high, but since it drives rightward in the state of this high contact pressure, powerful driving force is obtained. And since it descends so that it may secede from a driven object when a drive child returns leftward, the force will not reach, but a driven object will be driven rightward by the above repeat.

[0011] More generally in claim 1, the above-mentioned ellipse vibration upward slanting to the right was expressed. Although it is known as the so-called Lissajous figure that the phase contrast of vibration of the XY direction will serve as an ellipse upward slanting to the right by pi/4 in a rectangular coordinate system, the oscillating component in an ultrasonic vibrator does not necessarily intersect perpendicularly mutually. Then, it is claim 1 which was considered as the more general expression.

[0012] In claim 2, we decided that phase contrast is in pi/4 order, i.e., the range of 0 - pi/2, supposing the rectangular coordinate system.

[0013] In claim 3, phase contrast was more restrictively specified as pi/4, and the conditions of an and also [it is the need] were also added.

[0014] Hereafter, the example of the ultrasonic motorised equipment applied to this invention with reference to an accompanying drawing is explained. First, the example 1 of this invention is explained. <u>Drawing 1</u> is the perspective view showing an ultrasonic vibrator.

[0015] The basic elastic body 11 formed brass material in the **** type, and the dimension is 4mm in width of face of 30mm, and depth (except for heights), and it made ten kinds whose height H is 6-9mm as an experiment. The dimension of heights is 4mm in width of face of 4mm,

height of 2.5mm, and depth. The phi2mm stainless steel pin 16 is pressed fit in the location of 6mm from the base in the core of the cross direction of the basic elastic body 11.
[0016] The laminating mold piezoelectric device 12 carried out hundreds of several 10- sheet laminating of the piezoelectric device by which electrotreatment was carried out, and 2x3xNLA-9 molds (dimension 2mmx3.1mmx9mm) of Tokin Corp. were used for it by this example. In addition, side faces other than the both-ends side of the laminating mold piezoelectric device 12 are covered with epoxy system resin with a thickness of 0.5mm. The electrode to the laminating mold piezoelectric device 12 on the left-hand side of drawing is set to A and GND here, and the electrode to the right-hand side laminating mold piezoelectric device 12 will be similarly set to B and GND, and it will be called [an A phase, a call, and] a B phase.
[0017] Two laminating mold piezoelectric devices 12 and 12 are arranged so that the heights of the basic elastic body 11 may be put, they are put by the elastic members 13 and 13 (width of face of 4mm, height of 2.5mm, depth of 4mm) for maintenance by which the screw 14 stop was further carried out to the basic elastic body 11 from the both sides, and where compressive force is received in a longitudinal direction, they are being fixed. The both ends of the laminating mold piezoelectric device 12, the heights of the basic elastic body 11, and the elastic body 13 for maintenance are fixed with the adhesives of an epoxy system here. The contact surface of the laminating mold piezoelectric device 12 and the basic elastic body 11 is also pasted up with epoxy system adhesives.
[0018] The drive child 15 is the thing of the shape of a rectangle with width of face of 3mm which consists of grinding stone material which made resin distribute the abrasive grain of alumina ceramics, a thickness [of 1mm], and a depth of 4mm, and has pasted the location of 9mm from the both ends of the base of the basic elastic body 11. This location is equivalent to the antinode of crookedness vibration, and the amplitude of resonance crookedness vibration is the location which shows the maximal value.
[0019] Next, actuation of an ultrasonic vibrator is explained. According to the computer analysis by the finite element method, the primary resonance longitudinal oscillation as shown in drawing 2 (a), and the secondary resonance crookedness vibration as shown in this drawing (b) can excite the ultrasonic vibrator of the above-mentioned dimension on the same frequency mostly. The frequency is 53-56kHz. Then, it is amplitude 10 ****-p at this resonance frequency. The alternation electrical potential difference was impressed to the A phase and the B phase. When the phase of an A phase and a B phase was first made in phase, the primary resonance longitudinal oscillation as shown in drawing 2 (a) was excited. Next, when the phase of an A phase and a B phase was made into the opposite phase, the secondary resonance crookedness vibration as shown in drawing 2 (b) was excited. Furthermore, when the phase of an A phase and a B phase was shifted 90 degrees, ultrasonic ellipse vibration was excited by the drive child 15 neighborhood.
[0020] Below, the ultrasonic linear motor which used the above-mentioned ultrasonic vibrator is explained. Drawing 3 is the front view of an ultrasonic linear motor. With this ultrasonic linear motor, the driven object slack migration section 32, the slide member attaching part 33, and a slide member 34 drive the fixed part 30 top of a cloth roller guide right and left with an ultrasonic vibrator 10 as illustration.
[0021] The ultrasonic vibrator 10 is pivoted between two maintenance plates 21 by the pin 16, and the screw 23 stop of the maintenance plate 21 is carried out to the attachment member 22, and it is shown to the attachment member 22 to it to it by the linear bush 24 free [sliding] in accordance with the shaft 25. Moreover, the shaft 25 is being fixed to the pedestal 27 through the holddown member 26. Therefore, the ultrasonic vibrator 10 has the degree of freedom of rotation of the circumference of a pin 16, and the degree of freedom by vertical migration of a pin 16. And between said holddown members 26 and attachment members 22, the spring 29 which can carry out adjustable [of the thrust] with a stretching screw 28 is infixed.
[0022] The screw 31 stop is carried out to the pedestal 27, on the other hand, the slide member 34 which consists of zirconia ceramics through the slide member attaching part 33 has pasted the migration section 32 of a cloth roller guide, and the fixed part 30 of a cloth roller guide touches the drive children 15 and 15 of an ultrasonic vibrator 10.
[0023] Below, actuation of this ultrasonic linear motor is explained. The alternation electrical potential difference of 53-56kHz is impressed to the A phase and B phase of an ultrasonic vibrator 10 as mentioned above, and phase contrast is made into 90 degrees (or -90 degrees).

Then, ultrasonic ellipse vibration is excited by the drive child 15 of an ultrasonic vibrator 10, and the migration section 32 moves to right and left. Then, ten kinds of ultrasonic vibrators with which height H differs as mentioned above were made as an experiment, and the motor property was evaluated. The result is shown below.
[0024]
[Table 1]

試作番号	縦共振周波数	屈曲共振周波数	モータ動作
0	54.50	51.50	×
1	54.40	52.90	○
2	54.90	53.90	○
3	54.00	53.60	○
4	54.40	54.05	○
5	54.70	54.60	○
6	54.50	54.50	△
7	54.90	55.30	×
8	54.75	55.65	×
9	54.45	55.85	×

[0025] In Table 1, it is shown that the motor actuation O mark operated good, and although ** mark operates, it is shown whether a very unstable thing and x mark operate at all and that a thrust and a rate were hardly obtained even if it operated. Moreover, drive frequency was more than the crookedness oscillating resonance frequency of front Naka, and was below longitudinal-oscillation resonance frequency (the unit of a table is kHz). From this result, when crookedness oscillating resonance frequency was not below longitudinal-oscillation resonance frequency, not operating to stability became clear.
[0026] To the above experimental result, in order to explore the cause, the following experiments were conducted. As shown in drawing 4 , the piezoelectric device 110 by which polarization was carried out to the side face of an ultrasonic vibrator 100 in the thickness direction as an oscillating sensing element was pasted up. This piezoelectric device is 0.3mm in width of face of 10mm, height of 3mm, and thickness. An adhesion location is right above [of a drive child]. It pasted up so that the sense of polarization might turn [field / of the side front of vibrator] to identitas, and it connected to the serial, and considered as F1 terminal. In the rear face of vibrator, the polarization sense was made reverse to mutual, and it considered as F2 terminal. F1 terminal detects only the longitudinal oscillation of an elastic body, and F2 terminal detects only crookedness vibration so that the oscillation mode of drawing 2 may show.
[0027] Now, the longitudinal oscillation at the time of electrical-potential-difference impression and crookedness vibration were detected to coincidence with F1 and F2 terminal about the ultrasonic vibrator to the prototype numbers 0-9. The result is shown in drawing 5 . In this drawing, the driven object located up drives to a longitudinal direction. Moreover, that it is with positive/negative expresses the time of the forward direction drive and the negative direction drive.
[0028] Drawing 5 (a) has the shape of oscillatory type of the vibrator of the prototype number 0. It turns out that it is almost straight-line round trip vibration. In this case, although it does not operate or operates, a rate and a thrust hardly come out.
[0029] Drawing 5 (b) has the shape of oscillatory type of the vibrator of the prototype numbers 1-5. It has an ellipse upward slanting to the right. In this case, it is stabilized good and operates. When the phase contrast of crookedness vibration was set to +pi/4 or 5pi/4 especially to longitudinal oscillation (when it is the negative direction drive) (when it is the forward direction drive), the maximum thrust and the rate were obtained.
[0030] Drawing 5 (c) has the shape of oscillatory type of the vibrator of the prototype number 6. Although the perfect circle is shown in drawing, it becomes a longwise or oblong ellipse according to the amplitude difference of longitudinal oscillation and crookedness vibration in fact. At this time, actuation was unstable. When the main shaft of an ellipse was parallel to the driving direction of a driven object from now on, it turned out that actuation becomes unstable.
[0031] Drawing 5 (d) has the shape of oscillatory type of the vibrator of the prototype numbers

7-9. Although it does not operate in this case, either or operates, a rate and a thrust hardly come out.
[0032] The above experimental result showed a motor being stabilized and not operating, unless it is an ellipse vibration upward slanting to the right as shown in drawing 5 (b).
[0033] This means that it is in the range of 0 - pi/2 before and after phase contrast sandwiched pi/4, if it thinks by the Lissajous figure of XY rectangular coordinate system. Furthermore, as indicated to claim 1 in addition to the rectangular coordinate system, it means that the angle of the vector of the direction which is the vector of the direction of a major axis of ellipse vibration, and approaches a driven object, and the velocity vector of the direction which is the velocity vector of the tangential direction of this ultrasonic ellipse vibration, and a driven object drives to make turns into an acute angle.
[0034] Next, when the sweep of the amplitude of each oscillation mode and the relation of a phase to applied voltage was carried out and the frequency was investigated to the vibrator of the prototype numbers 0-9, it became like drawing 6 . In drawing, fl is the resonance frequency of longitudinal oscillation and fb is the resonance frequency of crookedness vibration.
[0035] In the case of the vibrator of the prototype number 0, longitudinal-oscillation mode corresponded to the oscillation mode 1, crookedness vibration corresponded to the oscillation mode 2, and the phase contrast between fl and fb was pi/2.
[0036] In the case of the vibrator of the prototype numbers 1-5, longitudinal-oscillation mode corresponded to the oscillation mode 1, crookedness vibration corresponded to the oscillation mode 2, and the phase contrast between fl and fb exceeded 0, and was less than pi/2.
[0037] Although longitudinal-oscillation mode corresponded to the oscillation mode 1 in the case of the vibrator of the prototype number 6 and crookedness vibration corresponded to the oscillation mode 2, most both curves were in agreement. For this reason, fl and fb were in agreement and phase contrast was 0.
[0038] It was longitudinal oscillation that it is the crookedness oscillation mode to deal with the oscillation mode 1 in the case of the vibrator of the prototype numbers 7-9, and it deals with the oscillation mode 2, and the phase contrast between fl and fb was zero or more.
[0039] As indicated from the above experimental result to claim 3 as an ultrasonic vibrator Set up the resonance frequency of longitudinal oscillation more highly than the resonance frequency of crookedness vibration, and it sets to the frequency range more than the resonance frequency of crookedness vibration below with the resonance frequency of longitudinal oscillation. Phase contrast deltaa of vibration to the alternation electrical potential difference of longitudinal oscillation It turned out that it is desirable that phase contrast deltab of vibration to the alternation electrical potential difference of crookedness vibration forms in the configuration used as 0<(deltaa-deltab) <+pi/2. And the actuation stabilized when the alternation electrical potential difference from which a phase differs ** pi/2 in the frequency range more than the resonance frequency of crookedness vibration was impressed to the laminating mold piezoelectric device below with the resonance frequency of longitudinal oscillation at this time is obtained.
[0040] However, the above thing is realized when the resonance frequency of an ultrasonic vibrator is fixed, in an actual ultrasonic vibrator, while in use, an about 30-degree C temperature rise arises, and resonance frequency falls [longitudinal oscillation and crookedness vibration].
[0041] Then, consider as a drive circuit as shown in drawing 7 , and the detecting signal from F1 and F2 terminal is inputted into a comparison controller. Based on the information on these oscillating detection means, the phase contrast theta of the crookedness vibration to longitudinal oscillation 0<theta<+pi/2, Or the frequency and phase of an alternation electrical potential difference which are impressed to two laminating mold piezoelectric devices were controlled below by the resonance frequency of longitudinal oscillation in the frequency range more than the resonance frequency of crookedness vibration to be set to + pi<theta <+3pi/2. That is, a comparison controller controls the oscillation frequency of an oscillator and controls phase contrast by the phase shifter further. This is amplified and an alternation electrical potential difference is impressed to an A phase and a B phase.
[0042] In this example, the thrust and rate which were stabilized even if it was the case where the temperature of an ultrasonic vibrator changed with the above control, and resonance frequency shifted were obtained. In addition, although two laminating mold piezoelectric devices were used in this example, also when three or more electric machine sensing elements are used,

it can apply.
[0043]
[Example 2] Next, the example 2 of this invention is explained. Drawing 8 is the block diagram showing the drive circuit of this example. The ultrasonic vibrator, the configuration of a linear motor, and the operation are the same as that of an example 1. In this example, the phase contrast of the alternation electrical potential difference impressed to the A phase of an ultrasonic vibrator and a B phase was fixed to ** pi/2. And only the frequency was controlled by the comparison controller. That is, based on the information on F1 and F2, the comparison controller of drawing 8 is a frequency range more than the resonance frequency of the crookedness vibration below with the resonance frequency of longitudinal oscillation, and outputs to an oscillator the signal which controls the frequency of the alternation electrical potential difference impressed to two laminating mold piezoelectric devices so that the phase contrast theta of the crookedness vibration to longitudinal oscillation may be set to theta=pi / 4, or theta=5pi/4.
[0044] In this example, the thrust and rate which were stabilized even if it was the case where the temperature of an ultrasonic vibrator changed with the above control, and resonance frequency shifted were obtained. In addition, this example has the advantage to which circuitry becomes easy rather than an example 1.
[0045] In addition, although this invention is not limited to the above-mentioned example, compounded longitudinal oscillation and crookedness vibration in the above-mentioned example and ultrasonic ellipse vibration was obtained, even if it combines torsional oscillation, skid vibration, respiratory vibration, spread vibration, etc., it is realizable similarly, for example. Moreover, although applied about the ultrasonic motor of a linear mold in the above-mentioned example, the application to the ultrasonic motor of body of revolution, then a rotation mold is also possible in a mobile.
[0046]
[Effect of the Invention] The thrust and rate which were stabilized even if it was the case where according to the ultrasonic motorised equipment of this invention the temperature of an ultrasonic vibrator changed and resonance frequency shifted, as explained above are obtained.

TECHNICAL FIELD

[Industrial Application] This invention relates to ultrasonic motorised equipment.

PRIOR ART

[Description of the Prior Art] Generally in an ultrasonic motor, ellipse vibration of the drive child in contact with a driven object is carried out, and driving force is generated. What is necessary is just to add in more detail vibration from which it is the same frequency and a phase differs to X shaft orientations and Y shaft orientations that what is necessary is just to compound two vibration of the direction which intersects perpendicularly mutually theoretically, in order to generate such ellipse vibration. Therefore, as long as this condition is fulfilled, various deformation as structure of the ultrasonic motor itself is possible, for example, the thing of the structure which stuck the piezoelectric device for the crookedness for right-and-left vibration on the side face of the laminating mold piezoelectric device of the shape of the structure which combined the laminating mold piezoelectric device in the two rectangular directions, and a rectangular parallelepiped for vertical vibration etc. is known.
[0003] Then, in Japanese Patent Application No. No. 321096 [four to], these people also fixed the elastic body for maintenance to three places of the top face of the elastic body of a rectangular parallelepiped configuration, and have proposed the ultrasonic vibrator of the structure which carried out pinching immobilization of the two laminating mold piezoelectric devices between each elastic body for maintenance. The resonance frequency of the longitudinal oscillation of an elastic body and crookedness vibration is designed by the dimension mostly in agreement, and this ultrasonic vibrator impresses the alternation electrical potential difference from which it is resonance frequency and a phase differs in two laminating mold piezoelectric devices. Then, ellipse vibration by which vibration of right and left by longitudinal oscillation and vibration of

the upper and lower sides by crookedness vibration were compounded by the drive child who fixed to the base of an elastic body occurs. Since the piezo-electric longitudinal effect of a piezoelectric device is used according to this ultrasonic vibrator, electric-machine conversion efficiency is high and the effectiveness which can be driven by the low battery is acquired.

EFFECT OF THE INVENTION

[Effect of the Invention] The thrust and rate which were stabilized even if it was the case where according to the ultrasonic motorised equipment of this invention the temperature of an ultrasonic vibrator changed and resonance frequency shifted, as explained above are obtained.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, with the equipment of above-mentioned point **, there was a trouble that dispersion by the individual difference of a product was large, and actuation was not necessarily stabilized. That is, when the resonance frequency of longitudinal oscillation and the resonance frequency of crookedness vibration were made strictly in agreement so that the detailed below-mentioned experimental result may see, or when actuation was unstable or it had shifted [whether the resonance frequency of longitudinal oscillation and the resonance frequency of crookedness vibration are merely slight, and], there were what operates good, and a thing which does not operate at all, and the cause was unknown. Moreover, when resonance frequency changed with temperature changes also about the same product, there was also a trouble that a rate and a thrust will decline.
[0005] It aims at offering the ultrasonic motorised equipment which this invention was not made in view of the above-mentioned trouble, and cannot be concerned with dispersion in a product, or change of a service condition, but can always be stabilized, and can drive an ultrasonic motor.

MEANS

[Means for Solving the Problem] It found out that a thrust and a rate optimal [a drive child's ultrasonic ellipse vibration] considering as an about (about [or] 5pi/4) pi/4 phase contrast ellipse and big were obtained, and artificers were stabilized, and operated.
[0007] Then, the ultrasonic motorised equipment of this invention which relates to claim 1 in order to attain the above-mentioned purpose Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. It is characterized by equipping with the following the ultrasonic motorised equipment which has the ultrasonic vibrator which carries out ultrasonic ellipse vibration of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element. The 1st oscillating detection means which detects only the above-mentioned longitudinal oscillation The 2nd oscillating detection means which detects only the above-mentioned crookedness vibration The vector of the direction which is the vector of the direction of a major axis of ultrasonic ellipse vibration excited to the above-mentioned drive child, and approaches a driven object based on the information on the above 1st and the 2nd oscillating detection means, The control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to two or more above-mentioned electric-mechanical energy sensing elements so that the angle made by the velocity vector of the direction which is the velocity vector of the tangential direction of this ultrasonic ellipse vibration, and a driven object drives turns into an acute angle
[0008] Moreover, the ultrasonic motorised equipment of this invention concerning claim 2 consists of an elastic body, a drive child who were fixed to this elastic body, and two or more electric - mechanical-energy sensing elements which were attached in this elastic body, and is characterized by to equip with the following the ultrasonic motorised equipment which has the driven object which has a synthetic vibration with longitudinal oscillation and crookedness

vibration excited by the above-mentioned elastic body, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric - mechanical-energy sensing element. The 1st oscillating detection means which detects the migration direction of the above-mentioned driven object for the above-mentioned longitudinal oscillation as a positive sense The 2nd oscillating detection means which detects the direction of [from the above-mentioned drive child] a driven object for the above-mentioned crookedness vibration as a positive sense the phase contrast theta of crookedness vibration of as opposed to the above-mentioned longitudinal oscillation based on the information on the above 1st and the 2nd oscillating detection means -- 0 < -- theta < -- +pi/2 or +pi < -- theta < -- Control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to said two or more electric-mechanical energy sensing elements below by the resonance frequency of the above-mentioned longitudinal oscillation in the frequency range more than the resonance frequency of the above-mentioned crookedness vibration to be set to +3pi/2

[0009] Moreover, the ultrasonic motorised equipment of this invention concerning claim 3 Consist of an elastic body, a drive child fixed to this elastic body, and two or more electric - mechanical energy sensing elements attached in this elastic body, and a synthetic vibration with longitudinal oscillation and crookedness vibration is excited to the above-mentioned elastic body. In the ultrasonic motorised equipment which has the ultrasonic vibrator which carries out ultrasonic ellipse vibration of the above-mentioned drive child, the driven object driven by the above-mentioned drive child, and the power source which impresses an alternation electrical potential difference to the above-mentioned electric-mechanical energy sensing element The 1st oscillating detection means which detects the migration direction of a driven object for the above-mentioned longitudinal oscillation as a positive sense, The 2nd oscillating detection means which detects the direction of [from a drive child] a driven object for the above-mentioned crookedness vibration as a positive sense, The resonance frequency of the above-mentioned longitudinal oscillation is set up more highly than the resonance frequency of the above-mentioned crookedness vibration, and it sets to the frequency range more than the resonance frequency of this crookedness vibration below with the resonance frequency of this longitudinal oscillation. phase contrast deltaa of vibration to the alternation electrical potential difference of this longitudinal oscillation Phase contrast deltab of vibration to the alternation electrical potential difference of this crookedness vibration 0 < -- (deltaa-deltab) < -- With the ultrasonic vibrator formed in the configuration used as +pi/2 Based on the information on the above 1st and the 2nd oscillating detection means, the phase contrast theta of the above-mentioned crookedness vibration to the above-mentioned longitudinal oscillation is theta. = pi/4 Or theta = Below with the resonance frequency of the above-mentioned longitudinal oscillation so that it may be set to 5pi/4 in the frequency range more than the resonance frequency of the above-mentioned crookedness vibration The control means which controls at least the frequency of an alternation electrical potential difference and one side of a phase which are impressed to said two or more electric-mechanical energy sensing elements is provided, and it is characterized by impressing the alternation electrical potential difference from which a phase differs ** pi/2 in two or more above-mentioned electric-mechanical energy sensing elements.

OPERATION

[Function] By controlling the frequency or phase of an alternation electrical potential difference to impress by the ultrasonic motorised equipment of this invention which consists of the above-mentioned configuration, it drives so that a drive child's ultrasonic ellipse vibration may serve as an about (about [or] 5pi/4) pi/4 phase contrast ellipse. as shown in drawing 5 (b), in phase contrast pi / 4, the ellipse vibration at this time draws an ellipse upward slanting to the right, when it is forward a driving direction -- rightward :, and when it is negative a driving direction -- leftward :, it draws the ellipse of a left riser in phase contrast 5pi/4. When a drive child will move rightward, going up if the case of the former is explained now, and it passes over the right best point, it turns out that the locus which returns leftward is taken, descending. That is, when going up so that a drive child may thrust up a driven object, the contact pressure to a

driven object becomes high, but since it drives rightward in the state of this high contact pressure, powerful driving force is obtained. And since it descends so that it may secede from a driven object when a drive child returns leftward, the force will not reach, but a driven object will be driven rightward by the above repeat.

[0011] More generally in claim 1, the above-mentioned ellipse vibration upward slanting to the right was expressed. Although it is known as the so-called Lissajous figure that the phase contrast of vibration of the XY direction will serve as an ellipse upward slanting to the right by pi/4 in a rectangular coordinate system, the oscillating component in an ultrasonic vibrator does not necessarily intersect perpendicularly mutually. Then, it is claim 1 which was considered as the more general expression.

[0012] In claim 2, we decided that phase contrast is in pi/4 order, i.e., the range of 0 - pi/2, supposing the rectangular coordinate system.

[0013] In claim 3, phase contrast was more restrictively specified as pi/4, and the conditions of an and also [it is the need] were also added.

[0014] Hereafter, the example of the ultrasonic motorised equipment applied to this invention with reference to an accompanying drawing is explained. First, the example 1 of this invention is explained. Drawing 1 is the perspective view showing an ultrasonic vibrator.

[0015] The basic elastic body 11 formed brass material in the **** type, and the dimension is 4mm in width of face of 30mm, and depth (except for heights), and it made ten kinds whose height H is 6-9mm as an experiment. The dimension of heights is 4mm in width of face of 4mm, height of 2.5mm, and depth. The phi2mm stainless steel pin 16 is pressed fit in the location of 6mm from the base in the core of the cross direction of the basic elastic body 11.

[0016] The laminating mold piezoelectric device 12 carried out hundreds of several 10- sheet laminating of the piezoelectric device by which electrotreatment was carried out, and 2x3xNLA-9 molds (dimension 2mmx3.1mmx9mm) of Tokin Corp. were used for it by this example. In addition, side faces other than the both-ends side of the laminating mold piezoelectric device 12 are covered with epoxy system resin with a thickness of 0.5mm. The electrode to the laminating mold piezoelectric device 12 on the left-hand side of drawing is set to A and GND here, and the electrode to the right-hand side laminating mold piezoelectric device 12 will be similarly set to B and GND, and it will be called [an A phase, a call, and] a B phase.

[0017] Two laminating mold piezoelectric devices 12 and 12 are arranged so that the heights of the basic elastic body 11 may be put, they are put by the elastic members 13 and 13 (width of face of 4mm, height of 2.5mm, depth of 4mm) for maintenance by which the screw 14 stop was further carried out to the basic elastic body 11 from the both sides, and where compressive force is received in a longitudinal direction, they are being fixed. The both ends of the laminating mold piezoelectric device 12, the heights of the basic elastic body 11, and the elastic body 13 for maintenance are fixed with the adhesives of an epoxy system here. The contact surface of the laminating mold piezoelectric device 12 and the basic elastic body 11 is also pasted up with epoxy system adhesives.

[0018] The drive child 15 is the thing of the shape of a rectangle with width of face of 3mm which consists of grinding stone material which made resin distribute the abrasive grain of alumina ceramics, a thickness [of 1mm], and a depth of 4mm, and has pasted the location of 9mm from the both ends of the base of the basic elastic body 11. This location is equivalent to the antinode of crookedness vibration, and the amplitude of resonance crookedness vibration is the location which shows the maximal value.

[0019] Next, actuation of an ultrasonic vibrator is explained. According to the computer analysis by the finite element method, the primary resonance longitudinal oscillation as shown in drawing 2 (a), and the secondary resonance crookedness vibration as shown in this drawing (b) can excite the ultrasonic vibrator of the above-mentioned dimension on the same frequency mostly. The frequency is 53-56kHz. Then, it is amplitude 10 ****-p at this resonance frequency. The alternation electrical potential difference was impressed to the A phase and the B phase. When the phase of an A phase and a B phase was first made in phase, the primary resonance longitudinal oscillation as shown in drawing 2 (a) was excited. Next, when the phase of an A phase and a B phase was made into the opposite phase, the secondary resonance crookedness vibration as shown in drawing 2 (b) was excited. Furthermore, when the phase of an A phase and a B phase was shifted 90 degrees, ultrasonic ellipse vibration was excited by the drive child 15 neighborhood.

[0020] Below, the ultrasonic linear motor which used the above-mentioned ultrasonic vibrator is explained. Drawing 3 is the front view of an ultrasonic linear motor. With this ultrasonic linear motor, the driven object slack migration section 32, the slide member attaching part 33, and a slide member 34 drive the fixed part 30 top of a cloth roller guide right and left with an ultrasonic vibrator 10 as illustration.
[0021] The ultrasonic vibrator 10 is pivoted between two maintenance plates 21 by the pin 16, and the screw 23 stop of the maintenance plate 21 is carried out to the attachment member 22, and it is shown to the attachment member 22 to it to it by the linear bush 24 free [sliding] in accordance with the shaft 25. Moreover, the shaft 25 is being fixed to the pedestal 27 through the holddown member 26. Therefore, the ultrasonic vibrator 10 has the degree of freedom of rotation of the circumference of a pin 16, and the degree of freedom by vertical migration of a pin 16. And between said holddown members 26 and attachment members 22, the spring 29 which can carry out adjustable [of the thrust] with a stretching screw 28 is infixed.
[0022] The screw 31 stop is carried out to the pedestal 27, on the other hand, the slide member 34 which consists of zirconia ceramics through the slide member attaching part 33 has pasted the migration section 32 of a cloth roller guide, and the fixed part 30 of a cloth roller guide touches the drive children 15 and 15 of an ultrasonic vibrator 10.
[0023] Below, actuation of this ultrasonic linear motor is explained. The alternation electrical potential difference of 53-56kHz is impressed to the A phase and B phase of an ultrasonic vibrator 10 as mentioned above, and phase contrast is made into 90 degrees (or -90 degrees). Then, ultrasonic ellipse vibration is excited by the drive child 15 of an ultrasonic vibrator 10, and the migration section 32 moves to right and left. Then, ten kinds of ultrasonic vibrators with which height H differs as mentioned above were made as an experiment, and the motor property was evaluated. The result is shown below.
[0024]
[Table 1]

試作番号	縦共振周波数	屈曲共振周波数	モータ動作
0	５４．５０	５１．５０	×
1	５４．４０	５２．９０	○
2	５４．９０	５３．９０	○
3	５４．００	５３．６０	○
4	５４．４０	５４．０５	○
5	５４．７０	５４．６０	○
6	５４．５０	５４．５０	△
7	５４．９０	５５．３０	×
8	５４．７５	５５．６５	×
9	５４．４５	５５．８５	×

[0025] In Table 1, it is shown that the motor actuation O mark operated good, and although ** mark operates, it is shown whether a very unstable thing and x mark operate at all and that a thrust and a rate were hardly obtained even if it operated. Moreover, drive frequency was more than the crookedness oscillating resonance frequency of front Naka, and was below longitudinal-oscillation resonance frequency (the unit of a table is kHz). From this result, when crookedness oscillating resonance frequency was not below longitudinal-oscillation resonance frequency, not operating to stability became clear.
[0026] To the above experimental result, in order to explore the cause, the following experiments were conducted. As shown in drawing 4 , the piezoelectric device 110 by which polarization was carried out to the side face of an ultrasonic vibrator 100 in the thickness direction as an oscillating sensing element was pasted up. This piezoelectric device is 0.3mm in width of face of 10mm, height of 3mm, and thickness. An adhesion location is right above [of a drive child]. It pasted up so that the sense of polarization might turn [field / of the side front of vibrator] to identitas, and it connected to the serial, and considered as F1 terminal. In the rear face of vibrator, the polarization sense was made reverse to mutual, and it considered as F2 terminal. F1 terminal detects only the longitudinal oscillation of an elastic body, and F2 terminal detects only crookedness vibration so that the oscillation mode of drawing 2 may show.
[0027] Now, the longitudinal oscillation at the time of electrical-potential-difference impression

and crookedness vibration were detected to coincidence with F1 and F2 terminal about the ultrasonic vibrator to the prototype numbers 0-9. The result is shown in drawing 5 . In this drawing, the driven object located up drives to a longitudinal direction. Moreover, that it is with positive/negative expresses the time of the forward direction drive and the negative direction drive.

[0028] Drawing 5 (a) has the shape of oscillatory type of the vibrator of the prototype number 0. It turns out that it is almost straight-line round trip vibration. In this case, although it does not operate or operates, a rate and a thrust hardly come out.

[0029] Drawing 5 (b) has the shape of oscillatory type of the vibrator of the prototype numbers 1-5. It has an ellipse upward slanting to the right. In this case, it is stabilized good and operates. When the phase contrast of crookedness vibration was set to +pi/4 or 5pi/4 especially to longitudinal oscillation (when it is the negative direction drive) (when it is the forward direction drive), the maximum thrust and the rate were obtained.

[0030] Drawing 5 (c) has the shape of oscillatory type of the vibrator of the prototype number 6. Although the perfect circle is shown in drawing, it becomes a longwise or oblong ellipse according to the amplitude difference of longitudinal oscillation and crookedness vibration in fact. At this time, actuation was unstable. When the main shaft of an ellipse was parallel to the driving direction of a driven object from now on, it turned out that actuation becomes unstable.

[0031] Drawing 5 (d) has the shape of oscillatory type of the vibrator of the prototype numbers 7-9. Although it does not operate in this case, either or operates, a rate and a thrust hardly come out.

[0032] The above experimental result showed a motor being stabilized and not operating, unless it is an ellipse vibration upward slanting to the right as shown in drawing 5 (b).

[0033] This means that it is in the range of 0 - pi/2 before and after phase contrast sandwiched pi/4, if it thinks by the Lissajous figure of XY rectangular coordinate system. Furthermore, as indicated to claim 1 in addition to the rectangular coordinate system, it means that the angle of the vector of the direction which is the vector of the direction of a major axis of ellipse vibration, and approaches a driven object, and the velocity vector of the direction which is the velocity vector of the tangential direction of this ultrasonic ellipse vibration, and a driven object drives to make turns into an acute angle.

[0034] Next, when the sweep of the amplitude of each oscillation mode and the relation of a phase to applied voltage was carried out and the frequency was investigated to the vibrator of the prototype numbers 0-9, it became like drawing 6 . In drawing, fl is the resonance frequency of longitudinal oscillation and fb is the resonance frequency of crookedness vibration.

[0035] In the case of the vibrator of the prototype number 0, longitudinal-oscillation mode corresponded to the oscillation mode 1, crookedness vibration corresponded to the oscillation mode 2, and the phase contrast between fl and fb was pi/2.

[0036] In the case of the vibrator of the prototype numbers 1-5, longitudinal-oscillation mode corresponded to the oscillation mode 1, crookedness vibration corresponded to the oscillation mode 2, and the phase contrast between fl and fb exceeded 0, and was less than pi/2.

[0037] Although longitudinal-oscillation mode corresponded to the oscillation mode 1 in the case of the vibrator of the prototype number 6 and crookedness vibration corresponded to the oscillation mode 2, most both curves were in agreement. For this reason, fl and fb were in agreement and phase contrast was 0.

[0038] It was longitudinal oscillation that it is the crookedness oscillation mode to deal with the oscillation mode 1 in the case of the vibrator of the prototype numbers 7-9, and it deals with the oscillation mode 2, and the phase contrast between fl and fb was zero or more.

[0039] As indicated from the above experimental result to claim 3 as an ultrasonic vibrator Set up the resonance frequency of longitudinal oscillation more highly than the resonance frequency of crookedness vibration, and it sets to the frequency range more than the resonance frequency of crookedness vibration below with the resonance frequency of longitudinal oscillation. Phase contrast deltaa of vibration to the alternation electrical potential difference of longitudinal oscillation It turned out that it is desirable that phase contrast deltab of vibration to the alternation electrical potential difference of crookedness vibration forms in the configuration used as 0<(deltaa-deltab) <+pi/2. And the actuation stabilized when the alternation electrical potential difference from which a phase differs ** pi/2 in the frequency range more than the resonance frequency of crookedness vibration was impressed to the laminating mold

piezoelectric device below with the resonance frequency of longitudinal oscillation at this time is obtained.

[0040] However, the above thing is realized when the resonance frequency of an ultrasonic vibrator is fixed, in an actual ultrasonic vibrator, while in use, an about 30-degree C temperature rise arises, and resonance frequency falls [longitudinal oscillation and crookedness vibration].

[0041] Then, consider as a drive circuit as shown in drawing 7 ; and the detecting signal from F1 and F2 terminal is inputted into a comparison controller. Based on the information on these oscillating detection means, the phase contrast theta of the crookedness vibration to longitudinal oscillation 0<theta<+pi/2, Or the frequency and phase of an alternation electrical potential difference which are impressed to two laminating mold piezoelectric devices were controlled below by the resonance frequency of longitudinal oscillation in the frequency range more than the resonance frequency of crookedness vibration to be set to + pi<theta <+3pi/2. That is, a comparison controller controls the oscillation frequency of an oscillator and controls phase contrast by the phase shifter further. This is amplified and an alternation electrical potential difference is impressed to an A phase and a B phase.

[0042] In this example, the thrust and rate which were stabilized even if it was the case where the temperature of an ultrasonic vibrator changed with the above control, and resonance frequency shifted were obtained. In addition, although two laminating mold piezoelectric devices were used in this example, also when three or more electric machine sensing elements are used, it can apply.

[0043]

[Example 2] Next, the example 2 of this invention is explained. Drawing 8 is the block diagram showing the drive circuit of this example. The ultrasonic vibrator, the configuration of a linear motor, and the operation are the same as that of an example 1. In this example, the phase contrast of the alternation electrical potential difference impressed to the A phase of an ultrasonic vibrator and a B phase was fixed to ** pi/2. And only the frequency was controlled by the comparison controller. That is, based on the information on F1 and F2, the comparison controller of drawing 8 is a frequency range more than the resonance frequency of the crookedness vibration below with the resonance frequency of longitudinal oscillation, and outputs to an oscillator the signal which controls the frequency of the alternation electrical potential difference impressed to two laminating mold piezoelectric devices so that the phase contrast theta of the crookedness vibration to longitudinal oscillation may be set to theta=pi / 4, or theta=5pi/4.

[0044] In this example, the thrust and rate which were stabilized even if it was the case where the temperature of an ultrasonic vibrator changed with the above control, and resonance frequency shifted were obtained. In addition, this example has the advantage to which circuitry becomes easy rather than an example 1.

[0045] In addition, although this invention is not limited to the above-mentioned example, compounded longitudinal oscillation and crookedness vibration in the above-mentioned example and ultrasonic ellipse vibration was obtained, even if it combines torsional oscillation, skid vibration, respiratory vibration, spread vibration, etc., it is realizable similarly, for example. Moreover, although applied about the ultrasonic motor of a linear mold in the above-mentioned example, the application to the ultrasonic motor of body of revolution, then a rotation mold is also possible in a mobile.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the perspective view showing the ultrasonic vibrator by this invention.

[Drawing 2] It is drawing explaining the oscillation mode of the ultrasonic vibrator of drawing 1 .

[Drawing 3] It is the front view showing the ultrasonic linear motor by this invention.

[Drawing 4] It is the front view and rear view showing the ultrasonic vibrator by this invention.

[Drawing 5] It is drawing explaining an operation of this invention.

[Drawing 6] It is drawing explaining an operation of this invention.

[Drawing 7] It is the block diagram showing the drive circuit of the ultrasonic motorised equipment by the example 1 of this invention.

[Drawing 8] It is the block diagram showing the drive circuit of the ultrasonic motorised equipment by the example 2 of this invention.

[Description of Notations]

10 Ultrasonic Vibrator
11 Basic Elastic Body
12 Laminating Mold Piezoelectric Device
13 Elastic Member for Maintenance
15 Drive Child
16 Pin
21 Maintenance Plate
24 Linear Bush
25 Shaft
27 Pedestal
28 Stretching Screw
29 Spring
30 Cloth Roller Guide Fixed Part
32 Cloth Roller Guide Migration Section
34 Slide Member

[Translation done.]